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ABSTRACT. Piglets from birth to wean at 21 days of age were subjected to heat lamps with either constant power output (CO) of 175 W or variable power output (VO) from 175 W at birth to 100 W by weaning time. Each type of heat lamp had either clear or red radiant rays. The effects of lamp output and color on heat lamp usage (HLU) and average daily gain (ADG) of the piglets were examined for a cool air temperature of 18 ± 1°C (65 ± 2°F) and a warm air temperature of 27 ± 1°C (80 ± 2°F). Increase of air temperature from 18 to 27°C significantly reduced HLU (55% vs 9%; $P < 0.05$) and ADG (270 vs 231 g/day; $P < 0.05$). HLU or ADG was similar for both types of lamp output. However, replacement of CO lamp with VO lamp would yield an annual energy saving of $29 (assuming electricity cost of $0.10/kWh and 320 days or 88% of annual farrowing crate occupancy). Heat lamp color showed no effect on piglet behavior or performance. A practical, low-cost operant controller that operates the heat lamps based on the presence/absence of piglets in the heat zone should be investigated to achieve additional energy savings in creep heating.
Keywords. *Creep heating, Swine farrowing, Energy efficiency, Heat lamp.*

A significant portion of the energy use in swine farrow-to-finish operations under the northern climates is in the form of supplemental heat by heat lamps during the lactation period (Barber et al., 1989). Heat lamps of 250 W had been the industry's primary source of localized heating for piglets. Localized creep heating is used to satisfy the different thermal needs of the piglets (32-35°C) and of the sow (18-21°C). A recent study by Xin et al. (1997) comparing the conventional 250 W heat lamps with an energy-efficient 175 W heat lamp revealed that the lower-wattage lamp not only saves energy (by 30%) but also reduces pre-weaning mortality (from 6.2% to 5.0%, $P < 0.05$). The study further revealed that the higher-wattage lamp produces excessive heat, which leads to uneven resting patterns of piglets under the heat lamps. Although there were no quantitative data, it was speculated that the excessive heat of the higher-wattage lamp could have driven the piglets away from the intended heat source, consequently increasing their likelihood of being crushed by the sow. A recent survey by the U.S. National Animal Health Monitoring System (Tubbs, 1996) indicated that a major profit loss for swine production is the pre-weaning piglet mortality (averaging 12 to 15% for the nation) that amounts to about 16 million pigs or $197.3 million per year in potential profits. Of the total pre-weaning mortality, 48% was from crushing. Thus, an improved creep heating and management method that reduces crushing would have significant economic ramifications.

Although replacing the 250 W heat lamp with the 175 W heat lamp improves energy use efficiency and piglet performance, the potential seemed to exist for additional energy savings by using variable-output heat lamps. This potential arose from the outcome that heat lamp usage of piglets decreases with age, as shown in our previous study (Xin et al., 1997). Also, there existed a speculation among some swine producers that color (especially red) lamps might be more attractive to piglets than the clear lamp. If so, use of such colored lamp could have a positive effect on reducing crushing losses. However, a search of literature revealed little information on the responses of piglets to light intensity (Rohde Parfet and Gonyou, 1991) or color rays.

The objectives of this study were to: (1) compare the effects of constant-output (CO) versus variable-output (VO) heat lamps on piglets; and (2) compare the effects of heat lamps color (clear vs red) on piglets. The effects of heat lamp output and color on piglets were evaluated for two ambient temperature conditions—one representing the winter/spring climate at 18°C (65°F) and the other representing the summer climate at 27°C (80°F).

MATERIALS AND METHODS

This study was conducted using an environmentally controlled room at the Iowa State University Swine Nutrition and Management Research Center in Ames, Iowa. The experimental room contained four farrowing crates (fig. 1) and measurement instruments (fig. 2). Each crate had the dimension of 1.5 m wide × 2.1 m long (5 ft × 7 ft), with a sow area of 0.6 m × 2.1 m (2 ft × 7 ft) along

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Figure 1–Photographic view of the experimental farrowing room. Heat lamps, two per crate, were suspended in the front of the crate. Electronic loadcell scales were situated below the heat lamps to continuously record presence of the piglets to monitor heat lamp usage of the piglets.

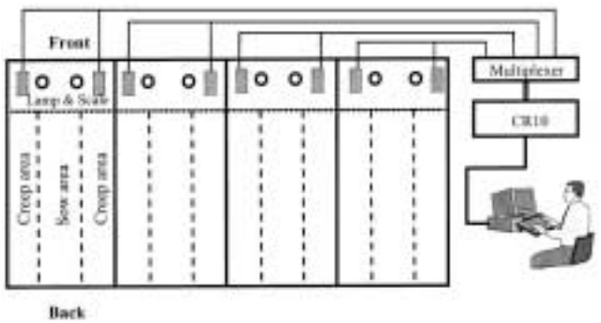

Figure 2–A schematic representation of the experimental farrowing crates, location of the heat lamps (open circles), low-profile electronic loadcell (shade blocks) scales under the heat lamps, and data acquisition devices. Heat lamps were located in the back of the crates during birth and less than two days of age.

the middle of the crate and a creep area of 0.46 m × 2.1 m (1.5 ft × 7 ft) on each side of the sow area. An area of 0.5 m × 1.5 m (1.67 ft × 5 ft) was added to the front of the crate where heat lamps were located after two days of age (fig. 2) and their usage by the piglets was automatically monitored. The experimental factors included two heat lamp output levels of CO (175 W) and VO (175 to 100 W), two lamp colors—clear and red—and two air temperatures, 18 ± 1°C (65 ± 2°F) and 27 ± 1°C (80 ± 2°F), with a concomitant relative humidity of 50% to 65%. Factorial (2×2×2) arrangement of the experimental factors gave a total of eight treatments. For each farrowing cycle/trial (lasting 21 days), the room temperature was maintained at either 18°C (65°F) or 27°C (80°F), and the four treatments of CO-clear, CO-red, VO-clear, and VO-red were randomly allotted to the four crates. Each treatment was replicated four times. Hence, a total of 32 litters (10 to 12 piglets/litter) were involved in the six-month trials. The lactating sows were fed twice daily (essentially ad-lib) with no creep feeding for the piglets. Continuous lighting was used.

The floors of each farrowing crate were made of woven wire for the sow area, of plastic slat for the creep area, and of woven wire covered with black rubber mat for the heat lamp area. To better distribute the lamp heat, two heat lamps were used per crate. They were suspended 45 cm (18 in.) above the floor or rubber mat. The heat lamps were turned on one day before the expected onset of farrowing, and were located in the back of the crate during parturition. The lamps were moved to and remained at the front of the crate after two days of age. The total wattage output per crate was equally divided between the two heat lamps. The variable wattage of the VO heat lamps was achieved with a rheostat controller (Model F911, Osborne Industries, Osborne, Kans.), and was started at 175 W (87.5 W/lamp) and lowered 12.5 W (6.25 W/lamp) every three days during the 21-day lactation period. The surface temperature of the rubber mats ranged from 30 to 45°C (86 to 113°F).

Heat lamp usage (HLU) by the piglets, defined as the percentage of litter mates using the heated area at the time of sampling, was continuously measured with a low-profile, platform loadcell scale (Model 642-A5-50kg-3MP2, Revere Transducers, Cerritos, Calif.) situated underneath the heated floor area at the front of the crate. The signal output of the scale (10 mV/[kg·V]) was sampled every 10 s with a PC-based data acquisition system (CR10 module, Campbell Scientific, Inc., Logan, Utah) and stored as 10-min averages. The number of pigs using the heated area was determined by dividing the projected piglet body weight into the total weight as measured by the loadcell scale. Because the loadcell scales were located in the front heated areas only, HLU was not monitored during the first two days when lamps were located in the back of the crate. Average daily gain (ADG) of the piglets was determined from the body weight at birth and weaning.

The effects of the treatments on piglet behavior and performance were analyzed using the General Linear Model procedure and Duncan's multiple mean comparison with a split-plot design (SAS, 1994).

Results and Discussion

The average HLU, ADG, pre-weaning mortality, lamp failure rate, and electricity use for the experimental treatments are presented in table 1. The daily HLU patterns from 3 to 20 days of age at 18°C (65°F) and 27°C (80°F) air temperatures are shown in figure 3 for the CO lamps and in figure 4 for the VO lamps.

Table 1. Heat lamp usage (HLU), average daily gain (ADG), and mortality rate of piglets and energy use of the heat lamps during a 21-day lactation period (Mean, standard error)*†

Heat Lamp Output	Room Temp	Lamp Color	HLU (%)	ADG (g/d)	Death (%)	Lamp Failure	Electricity Use (kWh/crt/d)
175 ~ 100 W	27 ± 1°C (80 ± 2°F)	Red	10(2)	229(4)	10.9(2.0)	1	3.3
		Clear	10(2)	238(12)	4.5(2.5)	0	3.3
		Avg./Tot.	10(1)^{b}	234(6)^{b}	7.7(1.9)^{a}	1	3.3
	18 ± 1°C (65 ± 2°F)	Red	58(4)	255(16)	2.5(2.5)	0	3.3
		Clear	57(2)	294(20)	10.3(4.0)	0	3.3
		Avg./Tot.	57(2)^{a}	274(14)^{a}	6.4(2.5)^{a}	0	3.3
	Overall		34(6)^{x}	254(8)^{x}	7.0(1.6)^{x}	1	3.3^{y}
175 W	27 ± 1°C (80 ± 2°F)	Red	6(2)	232(22)	6.1(2.0)	1	4.2
		Clear	8(3)	225(20)	4.5(2.5)	1	4.2
		Avg./Tot.	7(2)^{b}	228(14)^{b}	5.2(1.5)^{b}	2	4.2
	18 ± 1°C (65 ± 2°F)	Red	52(4)	266(9)	10.5(6.0)	0	4.2
		Clear	52(4)	265(13)	12.6(5.0)	0	4.2
		Avg./Tot.	52(3)^{a}	266(7)^{a}	11.5(3.7)^{a}	0	4.2
	Overall		30(6)^{y}	247(9)^{x}	8.4(2.2)^{x}	2	4.2^{x}

* Column means with different superscript letters of "a" and "b" within each type of heat lamp output differ significantly (P < 0.05) between the cool and warm room temperatures.

† Column means with different superscript letters of "x" and "y" differ significantly (P < 0.05) between the variable output and the constant output.

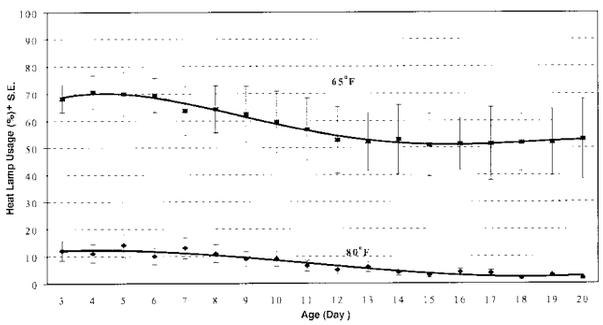

Figure 3–Daily average heat lamp usage of piglets subjected to constant-output heat lamp of 175 W at 18°C (65°F) or 27°C (80°F) air temperatures.

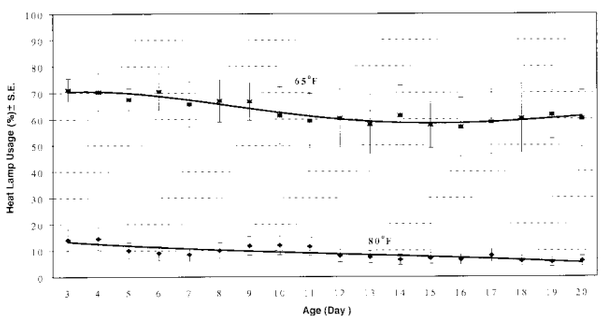

Figure 4–Daily average heat lamp usage of piglets subjected to variable-wattage heat lamp of 175 W to 100 W (decreasing at 12.5 W per three days) at 18°C (65°F) or 27°C (80°F) air temperature.

As can be noted from data in table 1, there was no significant difference in HLU between the clear and red heat lamps regardless of the output type or the ambient temperature levels tested (P > 0.05). This outcome was in contrast to the speculation that red-color heat lamps might be more attractive to the piglets than the clear ones. Hence, it would not be advisable for swine producers to spend extra money on red-color heat lamps for farrowing creep heating.

Because HLU was independent of the lamp color, pooled averages from both colors were used to determine the daily mean HLU at each room temperature. As shown in figures 3 and 4, HLU tended to be relatively constant during the first six days, especially at the cool room temperature. It then gradually declined with age. HLU tended to decline more quickly for the CO treatment than for the VO treatment, implying a better suitability of the VO heat lamp for the piglets. Furthermore, piglets subjected to the VO heat lamp had somewhat higher ADG (254 g/day) and lower mortality rate (7.0%) than piglets subjected to the CO heat lamp (247 g/day; 8.4%), although there was no statistical significance (P > 0.05) due to the large variability within the treatments. The relatively high mortality rates in this study were presumably attributed to the relatively small number of litters involved per treatment.

The ambient temperatures significantly affected HLU which averaged 52 to 57% for the cool temperature (18°C or 65°F) and 7 to 10% for the warm temperature (27°C or 80°F) (P < 0.05). This HLU outcome parallels that reported by Xin et al. (1996) for piglets during different production seasons of the year. The results suggest that a device that controls the operation of the heat lamps based on the dynamic thermal need of the piglets, e.g., day versus night where a substantial change in room temperature exists, would be conducive to both improved energy use efficiency and thermal comfort of the piglets. Curtis and Morris (1982) and Morrison et al. (1987) had made the same observations and suggestions for nursery pigs. Also as shown in table 1, the higher room temperature was associated with significantly lower ADG (228 to 234 g/d vs 266 to 274 g/d) (P < 0.05). This outcome was speculated to arise from the reduced feed intake and thus lower milk production of the sows under the warmer environment.

Perhaps the most attractive aspect of using the VO heat lamp lies in the energy savings of 21% or 0.9 kWh/crate/d compared with its CO counterpart. Assuming an annual farrowing crate occupancy of 320 days (88%) and an electricity cost of $0.10/kWh, the annual energy savings by the VO heat lamp would be $29/crate. At the retail price of approximately $30 per rheostat that can control two crates, the controller could be paid off in six months. The VO heat lamps also tend to have a better longevity than the CO heat lamps, a possible result of less heat load on the lamp filament. The same result was verified through a separate controlled experiment in our laboratory that compared the longevity of heat lamps that operated constantly or intermittently.

CONCLUSIONS

The following conclusions were drawn from this study:

- Heat lamps with a variable output (VO) from 175 W to 100 W seemed more suitable for creep heating than heat lamp with a constant output (CO) of 175 W throughout the 21-day lactation period. The VO heat lamp produced somewhat better ADG, slightly higher

heat lamp usage and piglet livability, and 21% energy savings compared to the CO heat lamp.

- Heat lamp color (clear or red) did not affect the performance of piglets or their behavior of using the heat lamps.
- Room temperature affects heat lamp needs by the piglets. The temperature of 27°C (80°F) significantly reduced ADG and heat lamp usage of the piglets compared to 18°C (65°F).
- Potentials exist for additional energy savings of heat lamps due to the dynamic and age-dependent supplemental heat needs of the piglets.

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